ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 1 2011

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YIELD AND EGGPLANT FRUIT QUALITY (*Solanum melongena* L.) DEPENDENT ON PLANT TRAINING AND NITROGEN FERTLIZATION

PLON I JAKOŚĆ OWOCÓW OBERŻYNY (*Solanum melongena* L.) W ZALEŻNOŚCI OD SPOSOBU PROWADZENIA ROŚLIN I NAWOŻENIA AZOTEM

Abstract: Studies upon the influence of varied forms and doses of nitrogen fertilizers as well as plant training on yields and eggplant fruit quality were carried out at The University of Life Sciences in Lublin in 2004–2005. Plants were trained in their natural form as well as for 3 carrying shoots. Following nitrogen nutrition forms were applied: ammonium (NH_4^+ – in a form of $(NH_4)_2SO_4$ 20.5 % N), nitrate (NO_3^- in a form of $Ca(NO_3)_2$ 13.5 % N), and amide (NH_2 in a form of $CO(NH_2)_2$ 46 % N), at following doses per 1 plant: 5, 10, 15 g N. Yields and number of fruits, as well as contents of dry matter, vitamin C and reducing sugars were determined.

It was found that the plant training method did not determine the size of eggplant fruit commercial yield, nor their number. Instead, it was observed that varied nitrogen rates significantly affected the yield size and fruit number. The highest yield was achieved when the highest nitrogen dose was applied (15 g N · plant^{-1} – 4.76 kg · m^{-2}), while the lowest yields were obtained after the lowest dose application (5 g N · plant^{-1} – 3.22 kg · m^{-2}). The average fruit number ranged to 17.7 fruits · m^{-2} and 11.7 fruits · m^{2}, respectively.

Achieved results referring to selected elements of fruit chemical composition indicated that the type of plant training did not influence on eggplant fruit quality. Varied nitrogen fertilization significantly affected the dry matter, ascorbic acid, and reducing sugars contents. Considering the yield size, fruit number, and reducing sugars contents, nitrate(V) form of nitrogen nutrition appeared to be the most favorable. Moreover, eggplant showed to have great requirements for nitrogen (15 g N · plant^{-1}).

Keywords: eggplant, training method, N form and dose, yield, vitamin C, sugars

Nice taste and great dietetic value of eggplant make that the vegetable finds more and more popularity in Poland and growing interests in its cultivation can be observed

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[1–6]. Its large thermal requirements determine the commercial plantations of eggplant under covers [7–9].

Domestic studies upon the eggplant cultivation revealed that even 10 kg fruits $\cdot$ m^{-2} can be obtained from eggplant grown in a greenhouse [10–13], while up to 6 kg fruits $\cdot$ m^{2} can be harvested from a plastic tunnel plantation [14–16]. The fertilization recommendations were worked out on a base of nutritional needs of tomato grown on an organic subsoil [17].

Taking into account growing interests in cultivating the eggplant in foil tunnels, it seems to be advisable to carry out studies upon its fertilization requirements in an aspect of yield quality [4–6, 18, 19].

Eggplant is a plant with great nutritional requirements, because it produces an enormous quantity of aboveground mass [20]. Therefore, many studies revealed that control of aboveground weight is necessary in eggplant cultivated under a cover. Cutting and training plants for 2–4 carrying shoots was assumed as optimum [8, 13, 21, 22].

The present study aimed at evaluating the influence of varied forms and doses of nitrogen nutrition on yields and quality of eggplant fruits that were cut and trained for 3 carrying shoots as well as in their natural form.

Material and methods

Study upon eggplant (*Solanum melongena* L.) of 'Epic' F_1 cv. was carried out in 2004–2005 in unheated plastic tunnel at The Experimental Farm of University of Life Sciences in Lublin in Felin. The eggplant seedling was prepared in a greenhouse according to rules recommended for that species. In both study years, seeds were sown at the beginning of March. Seedling was set into its place at the beginning of June. The vegetation period since seed sowing to the experiment completing lasted about 7 months (March 3 – September 13).

Plants were cultivated in foil cylinders of 10 dm^3 capacity each and at density of 3.3 plants per 1 m^2 (0.6 m × 0.5 m) on peat of initial pH 4.6, that was previously limed with $CaCO_3$ to pH = 6.5. The experiment was set in complete randomization design. Every combination was represented by 8 plants (experimental units).

The influence of three factors was examined:

1. Nitrogen forms:
   - NH_4^+ in a form of ammonium sulfate $(NH_4)_2SO_4$ (20.5 % N),
   - NO_3^- in a form of calcium nitrate $Ca(NO_3)_2$ (15.5 % N),
   - NH_2 in a form of urea $CO(NH_2)_2$ (46 % N),
2. Nitrogen doses: 5; 10; 15 g N $\cdot$ plant^{-1},
3. Method of plant training: natural; 3 shoots.

Nitrogen, phosphorus, potassium, and magnesium fertilization for the whole vegetation period amounted to (per 1 plant):

- nitrogen (N) – 5; 10; 15 g N in form of $(NH_4)_2SO_4$; $Ca(NO_3)_2$; $CO(NH_2)_2$,
- phosphorus (P) – 7.0 g P in form of $Ca(H_2PO_4)_2 \cdot H_2O$ – 20.2 % P,
- potassium (K) – 16 g K in form of K_2SO_4 – 41.6 % K,
- magnesium (Mg) – 7.0 g Mg in form of ($MgSO_4 \cdot H_2O$ 17.4 % Mg).

Applied microelements were added as: EDTA–Fe, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, $MnSO_4 \cdot H_2O$, H_3BO_3 and $(NH_4)_2Mo_7O_{24} \cdot 4H_2O$ at amounts analogous to peat subsoils. All microelements, 1/2 phosphorus, as well as 1/7 nitrogen, potassium, and magnesium doses were applied during the subsoil preparation, before plant setting. Another phosphorus dose was introduced after the first fruit harvest, while remaining amounts of nitrogen, potassium, and magnesium were applied top dressing in 6 rates every 10 days. The subsoil water content was maintained at the level of 70 %.

Nursery operations and plant protection was performed in accordance to recommendations for the species. Fruits were harvested from every plant at their commercial maturity stage (mean fruit mass about 280 g), that was determined by intensive purple color with characteristic metallic shine. The harvest was made every 7 days in both study years: the first one – at the end of July, the last one – in the mid of September. Following yielding parameters were determined: commercial yield and number of commercial fruits per m^2.

Fruit samples were collected for chemical analyses in the mid of fruiting period at their commercial maturity stage. Following items were determined in fresh fruits: dry matter – by means of drier method, ascorbic acid content – according to Tillmans method, reducing sugars – according to Schoorl–Rogenbogen procedure.

Achieved results were statistically processed applying variance analysis. The difference significance was verified using multiple T-Tukey confidence intervals at significance level of $\alpha = 0.05$.

Results and discussion

Due to very close values of determined parameters, they are presented as average for both study years. In 2004–2005, mean commercial yield of eggplant fruits amounted to $3.96\ kg \cdot m^{-2}$ (Table 1).

Variance analysis did not reveal significant influence of three applied nitrogen forms on eggplant commercial yield. Regardless of nitrogen rate, mean commercial yield was as follows: ammonium sulfate – $4.09\ kg \cdot m^{-2}$, calcium nitrate – $3.75\ kg \cdot m^{-2}$, urea – $4.04\ kg \cdot m^{-2}$. Regardless of nitrogen form, statistically significant effect of nitrogen dose on fruit commercial yield was observed. Applied doses: 5; 10; 15 $g\ N \cdot plant^{-1}$ significantly differentiated the size of eggplant commercial yield. Considerably higher average eggplant fruits commercial yield was achieved when applying 15 $g\ N \cdot plant^{-1}$ ($4.76\ kg \cdot m^{-2}$), next in the case of 10 $g\ N \cdot plant^{-1}$ application ($3.90\ kg \cdot m^{-2}$), and the lowest one when nitrogen dose equaled 5 $g\ N \cdot plant^{-1}$ ($3.22\ kg \cdot m^{-2}$). When three nitrogen forms were used, the largest differentiation of fruit commercial yield was recorded between the lowest and the highest dose. Varied methods of plant training – natural form and for 3 shoots – did not have any significant influence on eggplant fruit commercial yield: $4.09\ kg \cdot m^{-2}$ and $3.84\ kg \cdot m^{-2}$ were achieved, respectively.

Studies performed in 2004 and 2005 revealed average commercial yield of eggplant fruits foil as $3.96\ kg \cdot m^{-2}$. Comparison of here achieved results with other authors' ones: $3.34\ kg \cdot m^{-2}$ [14], $4.39\ kg \cdot m^{-2}$ [15], $4.33\ kg \cdot m^{-2}$ [16] indicates that here presented values are similar to those obtained by those authors; although Markiewicz

Table 1

The effect of nitrogen fertilizer and training method on the marketable yield and number of marketable fruit of eggplant

Kind of N fertilizer	N dose [g · plant^{-1}]	Marketable yield [kg · m^{-2}] Training method: Natural form	3 shoots	Means	Number of marketable fruit [No. · m^{-2}] Training method: Natural form	3 shoots	Means
$(NH_4)_2SO_4$	5	3.42	3.44	3.43	11.7	12.5	12.1
	10	4.62	4.07	4.34	14.1	14.4	14.2
	15	4.47	4.53	4.50	17.5	16.7	17.1
Mean for $(NH_4)_2SO_4$		4.17	4.01	4.09	14.4	14.5	14.4
$Ca(NO_3)_2$	5	3.07	2.72	2.90	10.6	9.2	9.9
	10	3.85	3.10	3.47	13.9	12.5	13.2
	15	4.82	4.96	4.89	18.1	17.1	17.6
Mean for $Ca(NO_3)_2$		3.91	3.59	3.75	14.2	12.9	13.6
$CO(NH_2)_2$	5	3.31	3.39	3.35	12.3	14.0	13.2
	10	3.95	3.81	3.88	13.7	16.2	15.0
	15	5.28	4.52	4.90	20.6	16.0	18.3
Mean for $CO(NH_2)_2$		4.18	3.91	4.04	15.5	15.4	15.5
Mean for dose N	5	3.27	3.18	3.22	11.5	11.9	11.7
	10	4.14	3.66	3.90	13.9	14.4	14.2
	15	4.86	4.67	4.76	18.7	16.6	17.6
Total mean		4.09	3.84	3.96	14.7	14.3	14.5
$LSD_{0.05}$	Kind N (a)			n.s.*			n.s.
	Dose N (b)			0.450			1.93
	Trainig method (c)			n.s.			n.s.
	Interaction: a b			1.032			4.19
	b c			0.773			3.14
	a c			n.s.			n.s.
	a b c			1.638			6.66

* n.s. – not significant.

and Golcz [4] recorded higher yields from plantation in a plastic tunnel – 8.37 kg · m^{-2}. Different nitrogen forms had not significant influence on yield size of eggplant fruits harvested from peat subsoil. Instead, significant dependence of yield on nitrogen rate was reported. Applying the largest nitrogen dose (15 g N · plant^{-1}) caused the increase of commercial yield by 48 % as compared with that achieved when the lowest nitrogen rate was applied (5 g N · plant^{-1}). Markiewicz and Golcz [4] in their study upon different levels of nutrients during eggplant cultivation on peat subsoil, recorded the largest yield increase (22 %) at the highest fertilization level.

Considering the results of fruit number, no significant effect of varied nitrogen forms on examined parameter were observed. Regardless of nitrogen dose, number of commercial eggplant fruits from plant fertilized with ammonium sulfate amounted to 14.4 m^{-2}, while when calcium nitrate and urea were applied equaled 13.6 fruits · m^{-2} and 15.5 fruits · m^{-2}, respectively. Regardless of nitrogen form, significant influence of nitrogen dose on that yielding parameter was found. Significantly larger number of commercial eggplant fruits (17.6 fruits · m^{-2}) was achieved due to application of 15 g N · $plant^{-1}$ as comparing with 10 g N · $plant^{-1}$ (14.2 fruits · m^{-2}), as well as to 5 g N · $plant^{-1}$ rate which resulted in significantly less number of fruits (11.7 fruits · m^{-2}). It was found that when nitrogen in its three forms was applied, the largest differentiation, referring to the fruit number, was recorded between its lowest and the highest dose. The type of eggplant training did not exert any considerable effect on examined parameter. From plants trained in their natural form as well as for 3 carrying shoots, 14.7 fruits · m^{-2} and 13.3 fruits · m^{-2}, respectively, were achieved.

Biological value was assesses on a base of dry matter, ascorbic acid, and reducing sugars contents at fresh eggplant fruits of 'Epic' F_1 cv. Results are presented in Table 2.

Dry matter content ranged from 6.77 % to 8.03 %, at mean value 7.42 %. A significant influence of varied nitrogen forms and doses on dry matter content was found, but no effect of plant training method was recorded. Significantly higher average value (7.7 1%) was reported for eggplant fruits from plants fertilized with NO_3^- form (calcium nitrate) as compared with other nitrogen forms. Furthermore, considerably higher dry matter content was found at fruits as a result of fertilization with nitrogen at 10 and 15 g N · $plant^{-1}$ rates as comparing with the lowest dose (Table 2). Studies made by Herrmann [1] and Kowalski et al [3] upon chemical composition of eggplant revealed similar content of dry matter in fruits.

Content of ascorbic acid at eggplant fruits amounted from 6.13 to 8.49 mg · 100 g^{-1} f.m. Among three examined factors, only nitrogen dose had significant influence on it (Table 2). Considerably lower content of ascorbic acid was found when the highest nitrogen rate was applied (15 g N) as compared with other ones. There is no information in available literature references on the effect of nitrogen doses on vitamin C content in eggplant fruits. Study performed by Kowalski et al [3] presented the evaluation of ascorbic acid content in fruits of several eggplant cultivars and it was concluded that it oscillated around 20 mg · 100 g^{-1} f.m. at 'Epic' F_1 cv., which was higher than that recorded by other authors: 5.54 mg · 100 g^{-1} f.m. [10] and 5.89 mg · 100 g^{-1} f.m. [14].

Considering the carbohydrates separated from a fresh matter of eggplant fruits, mean content of reducing sugars was determined (2.50 %). Similar sugars level at eggplant fruits was found by Herrmann [1], Cebula [10], as well as Ambroszczyk and Cebula [13, 23] at eggplant grown in a greenhouse, while Gajewski and Gajc-Wolska [14] found twice as much reducing sugars. The variance analysis revealed significant influence of applied nitrogen forms on reducing sugars contents: their highest level (2.60 %) was found at fruits of plants fertilized with urea (NH_2), whereas the lowest (2.31 %) at those treated with ammonium sulfate (NH_4^+). No effects of nitrogen dose on

Table 2

The content of dry matter vitamin C and reduced sugars in eggplant fruits depending on nitrogen fertilizer and training method

Kind of N fertilizer	N dose $[g \cdot plant^{-1}]$	Dry matter [%]			Vitamin C $[mg \cdot 100 g^{-1}$ f.m.]			Reduced sugars $[g \cdot 100 g^{-1}$ f.m.]		
		Training method			Training method			Training method		
		Natural form	3 shoots	Mean	Natural form	3 shoots	Mean	Natural form	3 shoots	Mean
	5	6.77	7.20	6.99	8.49	7.10	7.79	2.15	2.42	2.29
$(NH_4)_2SO_4$	10	7.60	7.02	7.31	8.08	7.32	7.70	2.18	2.23	2.21
	15	7.35	7.44	7.40	6.98	6.91	6.95	2.37	2.50	2.43
Mean for $(NH_4)_2SO_4$		7.24	7.22	7.23	7.85	7.11	7.48	2.23	2.38	2.31
	5	7.49	7.57	7.53	7.92	7.91	7.92	2.48	2.53	2.50
$Ca(NO_3)_2$	10	7.72	7.93	7.83	8.21	7.83	8.02	2.55	2.56	2.56
	15	7.53	8.03	7.78	6.70	7.32	7.01	2.59	2.76	2.68
Mean for $Ca(NO_3)_2$		7.58	7.84	7.71	7.61	7.69	7.65	2.54	2.62	2.58
	5	7.27	7.22	7.25	7.19	7.92	7.55	2.51	2.63	2.57
$CO(NH_2)_2$	10	7.36	7.19	7.27	6.72	7.32	7.02	2.40	2.77	2.58
	15	7.85	7.09	7.47	6.13	7.31	6.72	2.73	2.59	2.66
Mean for $CO(NH_2)_2$		7.49	7.17	7.33	6.68	7.52	7.10	2.54	2.66	2.60

Table 2 contd.

Kind of N fertilizer	N dose [g · plant^{-1}]	Dry matter [%]			Vitamin C [mg · 100 g^{-1} f.m.]			Reduced sugars [g · 100 g^{-1} f.m.]		
		Training method			Training method			Training method		
		Natural form	3 shoots	Mean	Natural form	3 shoots	Mean	Natural form	3 shoots	Mean
Mean for dose N	5	7.18	7.33	7.25	7.87	7.64	7.75	2.38	2.53	2.45
	10	7.56	7.38	7.47	7.67	7.49	7.58	2.38	2.52	2.45
	15	7.58	7.52	7.55	6.60	7.18	6.89	2.56	2.62	2.59
Total mean		7.44	7.41	7.42	7.38	7.44	7.41	2.44	2.56	2.50
$LSD_{0.05}$	Kind N (a)			0.222			n.s.			0.103
	Dose N (b)			0.222			0.733			0.103
	Trainig method (c)			n.s.			n.s.			0.070
	Interaction: a b			0.515			n.s.			0.239
	b c			0.384			n.s.			0.178
	a c			0.384			n.s.			0.178
	a b c			0.824			n.s.			0.382

reducing sugars contents at eggplant fruits were observed (Table 2). Instead, the effect of plant training method on reducing sugars content appeared to be significant. More sugars were found in fruits of plants that trained for three shoots rather than in natural form. This dependence can be explained by better light access, which determines the carbohydrate synthesis. It was earlier stated by studies made by Cebula [24], Ambroszczyk and Cebula [13] and Ambroszczyk et al [22].

Conclusions

1. The method of plant training did not determine the commercial yield and fruit number, nor dry matter and ascorbic acid contents at eggplant fruits; instead, it differentiated the reducing sugars content.

2. Applied nitrogen forms significantly affected the dry matter and reducing sugars contents at eggplant fruits, while they had no effect on yield and ascorbic acid level.

3. Applied nitrogen doses considerably affected the yield size, fruit number, and fruit quality.

4. At eggplant cultivated on peat subsoil, dose of 15 g N · plant^{-1} in a form of calcium nitrate should be considered as optimum nitrogen nutrition.

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PLON I JAKOŚĆ OWOCÓW OBERŻYNY (*Solanum molongena* L.) W ZALEŻNOŚCI OD SPOSOBU PROWADZENIA ROŚLIN I NAWOŻENIA AZOTEM

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Abstrakt: Badania nad wpływem zróżnicowanych form i dawek azotu oraz sposobu prowadzenia roślin na plon i jakość owoców oberżyny przeprowadzono w latach 2004–2005 w Uniwersytecie Przyrodniczym w Lublinie. Rośliny prowadzono w formie naturalnej oraz na 3 pędy przewodnie. Zastosowano zróżnicowane formy azotu: amonową (NH_4^+ – w postaci $(NH_4)_2SO_4$ 20,5 % N), saletrzaną (NO_3^- w postaci $Ca(NO_3)_2$ 13,5 % N) oraz amidową (NH_2 w postaci $CO(NH_2)_2$ 46 % N), stosując na 1 roślinę: 5, 10, 15 g N. Oceniono plon oraz liczbę owoców, a także zawartość w nich suchej masy, witaminy C i cukrów redukujących. Wykazano, że sposób prowadzenia roślin nie decydował o wielkości plonu handlowego owoców, a także o ich liczbie. Stwierdzono natomiast, że różnicowane dawki azotu istotnie oddziaływały na wielkość plonu i liczbę owoców. Największy plon uzyskano po zastosowaniu największej dawki azotu (15 g N · roślinę$^{-1}$ – średnio 4,76 kg · m^{-2}), a najmniejsze po zastosowaniu najmniejszej jego dawki (5 g N · roślinę$^{-1}$ – średnio 3,22 kg · m^{-2}). Liczba owoców wynosiła średnio odpowiednio 17,7 szt. · m^{-2} oraz 11,7 szt. · m^{2}.

Uzyskane wyniki dotyczące wybranych elementów składu chemicznego owoców wskazują, że sposób prowadzenia roślin nie miał wpływu na jakość owoców oberżyny. Natomiast zróżnicowane nawożenie azotem istotnie oddziaływało na zawartość suchej masy, witaminy C i cukrów redukujących. Mając na uwadze wielkość plonu, liczbę owoców oraz zawartość cukrów redukujących należy podkreślić korzystne oddziaływanie saletrzanej formy azotu oraz duże wymagania oberżyny w stosunku do tego pierwiastka (15 g N · roślinę$^{-1}$).

Słowa kluczowe: oberżyna, metody prowadzenia, formy azotu, dawki azotu, plon, witamina C, cukry